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Active Power Control in Siemens Wind Turbines

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Siemens Wind Turbines - Americas

What Are Common Active Power Control Requirements in the North America?

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Existing:

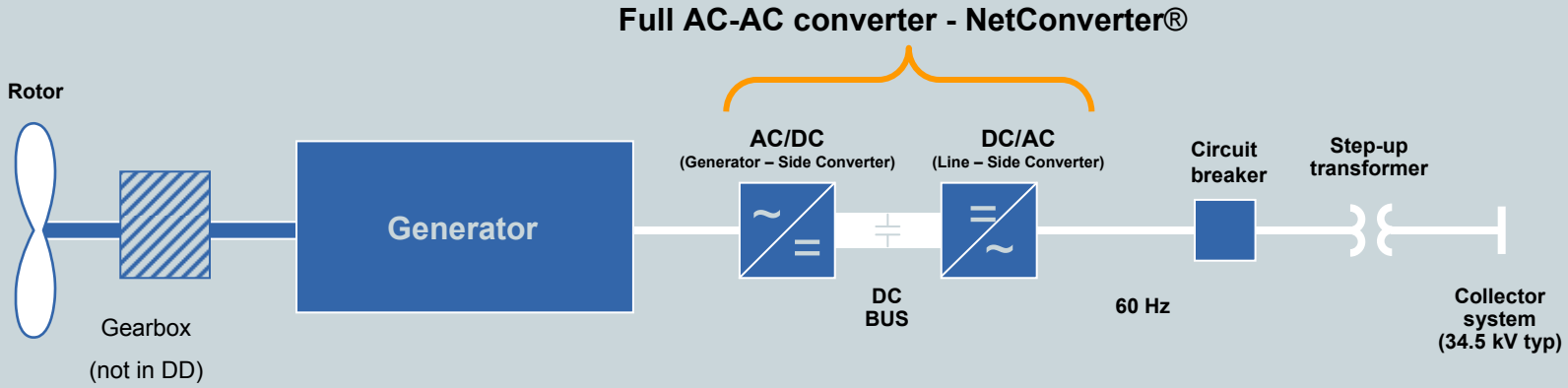
- Power Output (Curtailment) Control
- Ramp Rate Control
  - Curtailments
  - Start-up
- Regulation Up for Underfrequency
  - Adjustable Droop
- Regulation Down for Overfrequency
  - Adjustable Droop
- Spinning Reserve (Delta Control)
  - Frequency Responsive
  - Remote
- High Wind Shutdown

Expectation for New Requirements

Expected in the next 5 years:

- Automatic Generation Control (AGC) participation
- Transient Underfrequency (“Inertial”) Response

How Does the NetConverter® System Work?



- Rotor drives gearbox in geared systems – increases generator shaft speed to range of, typically, 600 to 1,600 rpm (variable speed)
- Gearbox eliminated in DD (direct drive); rotor directly drives low-speed, multi-pole generator
- Generator converts mechanical power to AC electric power. Generator can be asynchronous, permanent magnet or synchronous for geared system, pm or synchronous for DD.
- Generator-side converter converts AC electric power to DC
- Line-side converter converts DC to system-frequency AC (50 Hz or 60 Hz, as appropriate) and provides voltage regulation capability
- Converter decouples machine from grid, so no winding time constants – quick response

What are the Advantages of the NetConverter® System?

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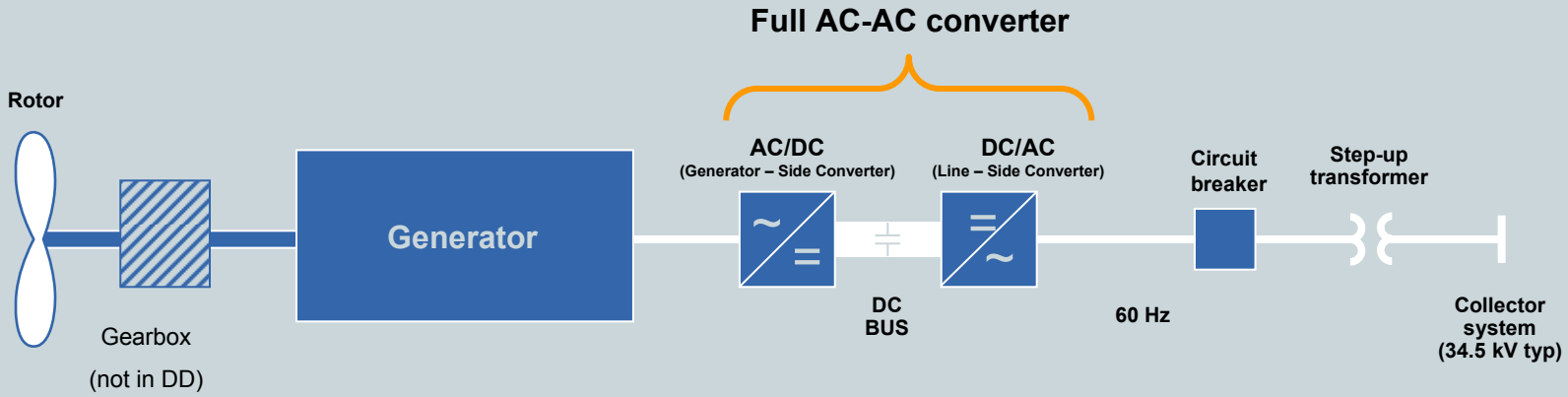

Variable Speed:

During abnormal conditions, can increase or decrease shaft speed/kinetic energy to satisfy system needs

- Increase shaft speed during low-voltage ride-through – extra kinetic energy stored in shaft when Pgen→0.
- Shaft can absorb energy from gusts without changing output

Full Converter:

Maximum flexibility and fast response; decouples machine:

- Rapid response – short time delays compared to directly connected magnetic machines, with winding time constants
- Precise control of output and rate of change of output as required (subject to availability of wind power)
- Turbine can be used for frequency response (for regulation down) or, with standby reserve, for spinning reserve/regulation up
- Decouples machine from power system – no SSTI, negative sequence heating concerns, minimal short circuit torques.

Ramp Rate Control - Smooth, Controlled Transition from One Output Level to Another

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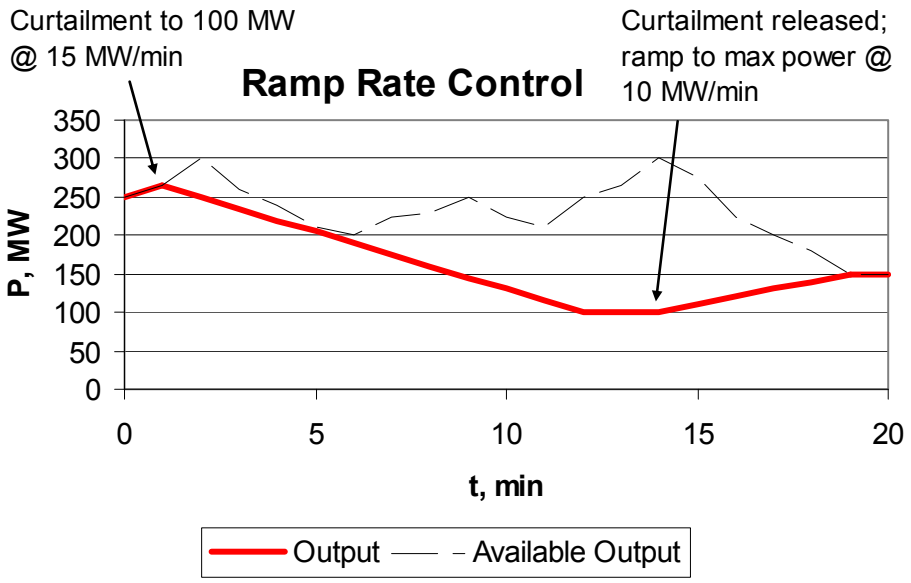
Some ISOs (e.g., ERCOT, some Canadian provinces) require ramp rate control to smoothly transition from one output level to another during curtailments.

- Ramp-rate control is available in Siemens WT park pilot for wind farms
- Can select any ramp rate (MW/min), assuming availability of adequate wind power



Delta Control – Operate with a Constant Delta Below Maximum Output

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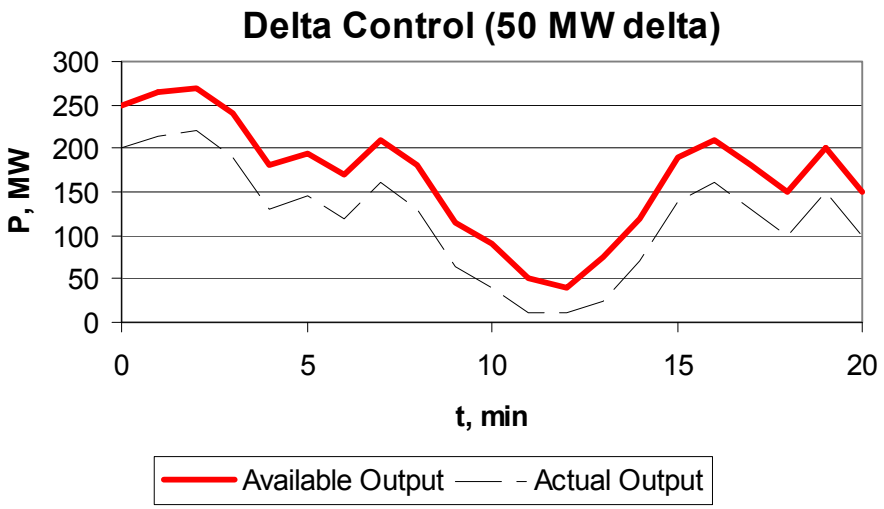
Some ISOs are considering the use of wind for regulation up and spinning reserve duty at some times of the day to release fossil capacity.

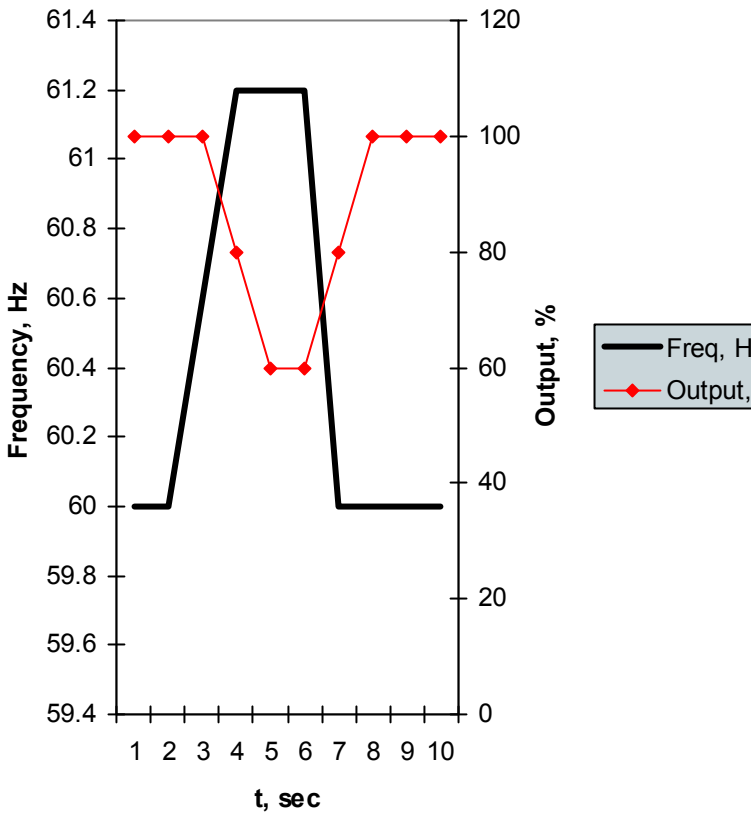
- Requires “spilling wind,” but may be the least expensive way to provide capability
- Can select any delta (MW) assuming availability of adequate wind power



Frequency Droop Control

Some ISO/RTOs require the use of frequency droop response from wind parks

- Normally constant (5%) frequency droop (5% change in freq → 100% change in output), but variable droop sometimes required (e.g., larger droop for small frequency excursions, smaller droop for larger excursions.
- Both reg up (underfreq), assuming curtailed state, and reg down (overfrequency) required.
- Sometimes conflicts w/ curtailments.



Recent Field Test Results – Regulation Down
Demonstrating Frequency Regulation for Overfrequency

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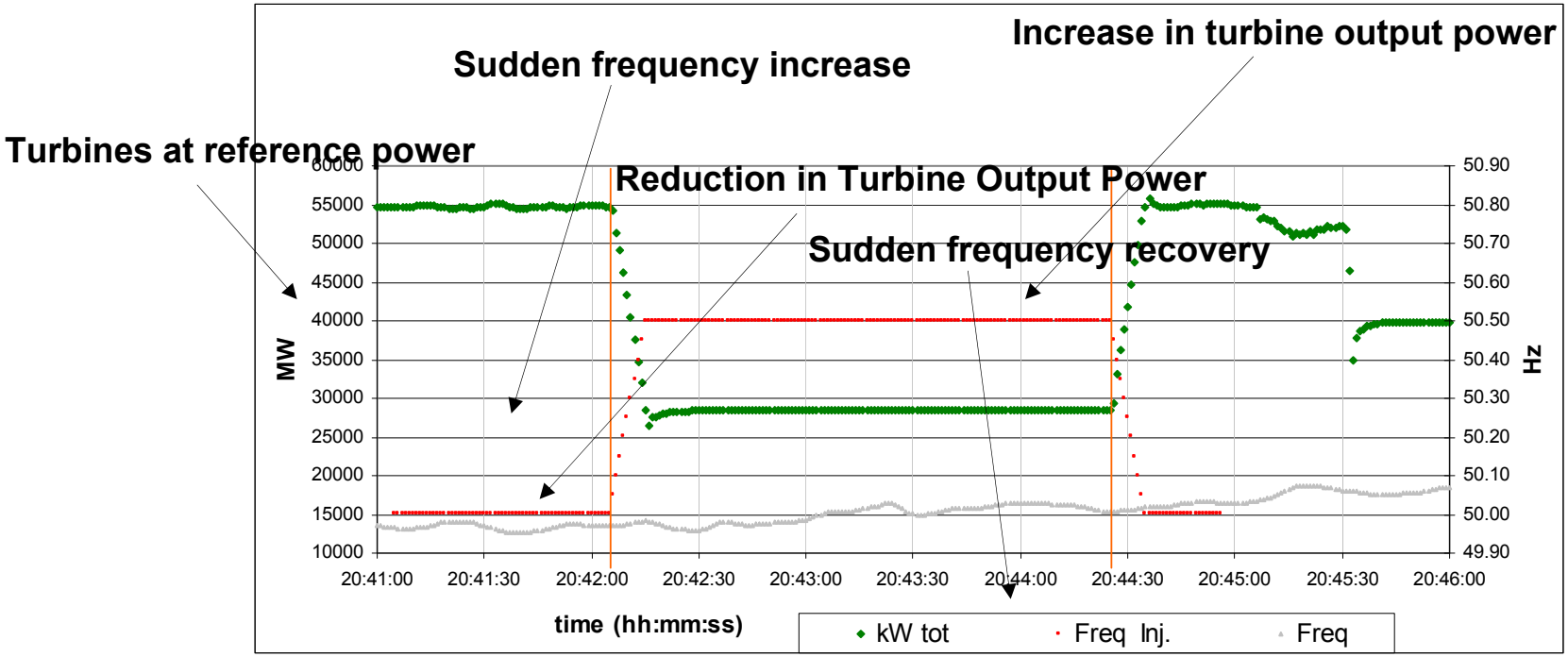
Recent results from test of "frequency control sensitive mode" (proportional droop response) – required by UK grid



Recent Field Test Results – Regulation Up
Demonstrating Frequency Regulation for Underfrequency

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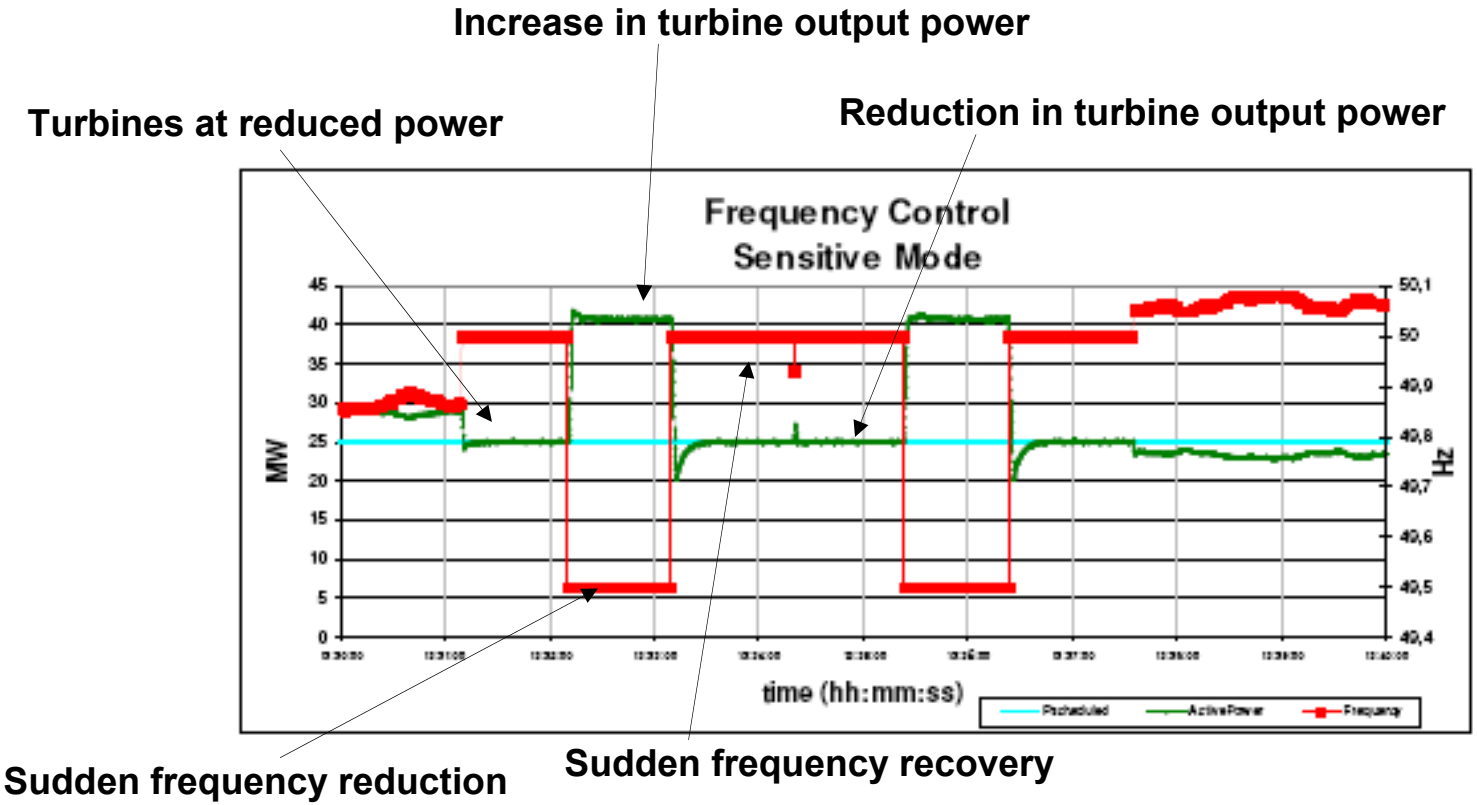
Recent results from test of "frequency control sensitive mode" (proportional droop response) – required by UK grid



Transient Underfrequency Response ("inertial response")

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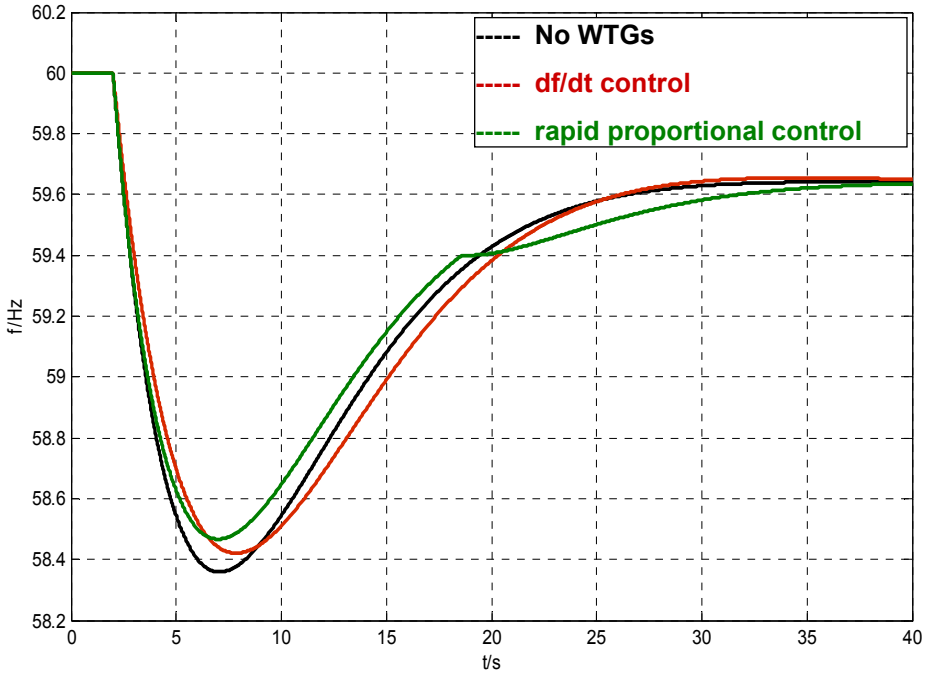
Rapid response required after sudden frequency drop – useful to forestall load shedding, especially on island systems.

Siemens is developing new controls to address this need.

Preliminary simulations for 20% wind case with different transient controls



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Automatic Generation Control (AGC) – What is it?

Slow control (30 sec typical); small adjustments to maintain Area Control Error (including tie line flows) within limits.

Normally communicated by analog pulse.

Can easily be converted to digital signal via A/D conversion.

Can be used to supplement P-command from Park RTU.

No clear reason to include in wind park controls, since wind parks are capable of very fast response (few sec for typical output response, if no ramp rate restrictions are imposed).

Probably best to include in Wind Park RTU, to sort out differences in conflicting requirements.

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High Wind Shutdown – What is it?

Ramp-down of power in anticipation of high-wind speed trip.

Reduces power loss and resulting frequency reduction caused by weather fronts.

Summary – How NetConverter® Wind Turbine Generators Satisfy Requirements (existing and anticipated)

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Capability	*Now*	*Soon*	
Power Output (Curtailment) Control			
Ramp-Rate Control (ref change and startup)			
Frequency Droop Governor Control			
Regulation up			
Regulation down			
Spinning reserve (“delta control”) capability			
Transient underfrequency (“inertial”) response			
High wind shutdown			
AGC Response (from Park RTU)			
Frequency-dependent droop			

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What do we need?

Inertial Response:

"True" inertial response is df/dt, but some vendors propose P, I, or P-I controls, resulting in response that is not inertial, but may be effective.

Need a clear set of performance requirements. Typical spec of "equivalent to synch generator with H = 4 sec", etc., ambiguous. Also, clarification of P,Q priority during circumstances when both frequency and voltage are low.

Standards (NERC? IEEE?) activity would be appropriate.

General Power Controls:

Clear delineation of priorities - resolution of conflicts between curtailments, ramp rates, frequency response, special protection systems, etc.

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Questions?